Active testing of groups at increased risk of acquiring SARS-CoV-2 in Canada: costs and human resource needs

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ABSTRACT

BACKGROUND: Testing for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is largely passive, which impedes epidemic control. We defined active testing strategies for SARS-CoV-2 using reverse transcription polymerase chain reaction (RT-PCR) for groups at increased risk of acquiring SARS-CoV-2 in all Canadian provinces.

METHODS: We identified 5 groups who should be prioritized for active RT-PCR testing: contacts of people who are positive for SARS-CoV-2, and 4 at-risk populations — hospital employees, community health care workers and people in long-term care facilities, essential business employees, and schoolchildren and staff. We estimated costs, human resources and laboratory capacity required to test people in

each group or to perform surveillance testing in random samples.

RESULTS: During July 8–17, 2020, across all provinces in Canada, an average of 41 751 RT-PCR tests were performed daily; we estimated this required 5122 personnel and cost $2.4 million per day ($67.8 million per month). Systematic contact tracing and testing would increase personnel needs 1.2-fold and monthly costs to $78.9 million. Conducted over a month, testing all hospital employees would require 1823 additional personnel, costing $29.0 million; testing all community health care workers and persons in long-term care facilities would require 11074 additional personnel and cost $124.8 million; and testing all essential employees would cost $321.7 million, requiring 25 965

added personnel. Testing the larger population within schools over 6 weeks would require 46 368 added personnel and cost $816.0 million. Interventions addressing inefficiencies, including saliva-based sampling and pooling samples, could reduce costs by 40% and personnel by 20%. Surveillance testing in population samples other than contacts would cost 5% of the cost of a universal approach to testing at-risk populations.

INTERPRETATION: Active testing of groups at increased risk of acquiring SARS-CoV-2 appears feasible and would support the safe reopening of the economy and schools more broadly. This strategy also appears affordable compared with the $169.2 billion committed by the federal government as a response to the pandemic as of June 2020.

To suppress the spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the pathogen responsible for coronavirus disease 2019 (COVID-19), many countries have adopted social-isolation measures.[1,2] These efforts have been largely successful but have had major economic implications. As of June 2020, the Canadian federal fiscal response alone was an estimated $169.2 billion.[3] Further, unemployment in June 2020 was 12%[4] and real gross domestic product is projected to fall 8.4% in 2020.[5] These consequences have led to demands to reopen the economy quickly.[6,7]

Reverse transcription polymerase chain reaction (RT-PCR) is primarily used to detect acute SARS-CoV-2.[8] Because of capacity constraints, RT-PCR testing was initially reserved for individuals presenting with symptoms consistent with COVID-19.[9–11] As capacity expanded and the initial wave of the epidemic was brought under control, however, testing was subsequently made available to people with minimal or no symptoms.[12] Modelling studies have estimated such individuals account for more than 50% of community transmission.[13–16] This is supported by studies that indicate viral shedding begins before symptom onset[17,18] and case series

that document substantial transmission from asymptomatic people.[19-22] Thus, testing of people with minimal or no symptoms appears to be an essential part of a comprehensive strategy to reopen the economy without creating epidemic recrudescence.[16]

Yet, the approach to testing has largely been passive,[23,24] placing the onus to be tested on the individual. People at increased risk of acquiring SARS-CoV-2 are unlikely to seek testing unless symptoms develop. An active strategy, in which all members of selected groups at increased risk of acquiring SARS-CoV-2 are tested, would act to identify people with infection but minimal or no symptoms. This would detect individuals who might otherwise contribute to transmission and provide important epidemiologic information on how SARS-CoV-2 is affecting these populations. Testing all members of workplaces and schools would support them in safely remaining open.

We aimed to estimate costs, human resources and laboratory capacity required for active testing strategies to detect SARS-CoV-2 using RT-PCR in groups at increased risk of infection in Canada.

Methods

Groups for active testing

We conceptualized 5 groups who should be prioritized for active testing strategies based on expected prevalence of infection with SARS-CoV-2 (Appendix 1, Figure e1, available at www.cmaj.ca/lookup/doi/10.1503/cmaj.201128/tab-related-content). The first group consisted of household and nonhousehold contacts of people who were newly diagnosed with SARS-CoV-2 infection (strategy 1), who would be systematically traced and tested to reach an average of 2 household and 14 nonhousehold contacts.[25,26] The remaining 4 groups comprised "at-risk populations." These included all employees of acute care hospitals (strategy 2); all community health care workers, and employees and residents of long-term care facilities (strategy 3); all non–health care employees of essential businesses with major interpersonal or public contact (strategy 4); and all students and employees in primary and secondary schools (strategy 5). For each group, we estimated costs, human resource needs and laboratory capacity associated with implementing active testing strategies that were additional to the status quo. We defined the status quo based on the testing performed between July 8 and 17, 2020, which includes testing of symptomatic people and limited testing of asymptomatic people (e.g., some individuals with exposure or at high risk of exposure).

Epidemiologic, testing and population parameters

We collected SARS-CoV-2 epidemiologic and testing information and estimated the size of the groups to be tested in all Canadian provinces (as of July 17, 2020, no active cases of COVID-19 existed in Canada's territories, so they were not considered) (Appendix 1, Table e1).

As of July 17, 2020, there were 488 SARS-CoV-2 testing sites; the estimated RT-PCR laboratory capacity was 80 750 tests per day. Over the period of July 8–17, 2020, 417 508 tests for SARS-CoV-2 were performed and 3501 (0.84%) were positive[27] (Appendix 1, Table e2).

Data from Statistics Canada provided the number of acute care hospitals and long-term care facilities,[28,29] the number of employees for each in June 2020,[4,30] and the number of residents of long-term care facilities.[31,32] Without an estimate of the number of community health care workers in Canada,[33] we used American data[34-36] and assumed the number employed in Canada was proportional to population. Census data from 2016 estimated the number of people employed under each national occupation code,[37] which were adjusted to June 2020 labour force size.[4] Three authors (J.R.C., N.W., S.L.) independently classified occupations as essential using Quebec's stringent definition from March 2020.[38] Using a published algorithm,[39] validated with O*Net,[40] we classified essential occupations as those not able to be performed at home. We then classified each of these occupations as being at high risk of interpersonal or public contact (Appendix 1, Table e3). Statistics Canada data[41] and provincial reports provided estimates of the number of primary and secondary schools and number of students and employees. Additional detail is shown in Appendix 1, Table e4.

Strategies for testing: costs and human resource requirements

To inform implementation of active testing strategies, we developed a conceptual framework for testing that consisted of 6 stages, which was used for each of the 5 groups: 1) scheduling, 2) sampling, 3) test transport, 4) laboratory RT-PCR analysis, 5) communication of results and 6) acting on results (e.g., contact tracing). Through discussion with public health officials and laboratory managers in Quebec, we estimated human resource requirements for each stage of each strategy. Full details of how each strategy would be conducted are shown in Appendix 1. In brief, we estimated the number of health care professionals, clerical and laboratory personnel required per day (1 d was 8 h; we considered part-time staff) for each strategy. We assumed sampling could be done at existing sampling centres by nurses or onsite by mobile teams. Mobile teams would visit health care facilities with ≥ 5 employees, essential businesses with ≥ 20 employees, and all schools; all others (including contacts) would be referred to existing sampling centres. We employed a microcosting approach for all recurrent costs (2020 Canadian dollars), using a health system perspective. These included costs of materials (e.g., personal protective equipment [PPE], nasopharyngeal swabs, reagents), personnel and transportation. We obtained costs from nationally representative sources. We did not include capital costs of scaling capacity (e.g., equipment, training) or existing infrastructure.

Analysis of universal testing

We estimated costs, human resources and laboratory capacity required to perform testing for each strategy, assuming 100% of each target population was tested. We calculated estimates for each province individually and summed them. We posited that systematic tracing and testing of contacts would remain a priority — as it is with other infectious diseases[42] — so we assumed this would continue. Therefore, we report the monthly cost associated with systematic tracing and testing contacts. For at-risk populations, testing may occur once or repeatedly, depending on prevalence and infection risk. Therefore, we report cost, human resource and laboratory capacity estimates for 1 complete round of testing over time intervals we considered feasible; we also report estimates if testing of at-risk populations was conducted while systematic tracing and testing

of contacts were continued. We assumed 1 complete round of testing would take 28 days for hospitals, community health care workers, long-term care facilities and essential businesses, and 42 days for the larger population in schools.

We separately calculated downstream costs of repeat testing and contact tracing and testing for each strategy. For the strategy of systematic tracing and testing of contacts, we estimated costs associated with 1 repeat test for contacts testing negative and 2 repeat tests for contacts testing positive. For strategies involving at-risk populations, we estimated costs of 2 repeat tests for each person testing positive, and the cost of tracing and providing the initial test to 16 contacts for each person testing positive.

Analysis of surveillance and repeated testing

Depending on epidemic stage and population prevalence, testing all people in at-risk populations may not be necessary, and surveillance-based testing — in which random samples of the population are tested — may be preferable. We estimated costs, human resources and laboratory capacity required to perform surveillance testing over 14 days in at-risk populations. We calculated the sample size needed for each group to estimate prevalence of SARS-CoV-2 infection using the estimated prevalence on July 17, 2020, (Appendix 1, Table e5) and if the prevalence were 10 times higher (Appendix 1, Table e6). We estimated sample sizes at the 95% confidence level, adjusting for finite sample size,[43] and assuming the cluster size was 10% of individuals from each school or facility. Further detail is shown in Appendix 1.

To inform when to repeat testing of at-risk populations, we estimated the time to a new SARS-CoV-2 infection based on group size and daily risk of infection. We evaluated group sizes of 10 to 1000 with daily risks of infection of 1 per 100 000 to 1 per 100 (assuming a communicability period of 10 days;[44] these daily risks approximate population prevalence estimates of 0.01% to 10%, respectively). Using a binomial distribution with these parameters, we ran 1000 simulations in R (version 3.6.3) over a 2-year period. From these simulations, we calculated the 10th, 25th and 50th percentile of the time to first infection (see Appendix 1 for code).

Sensitivity analyses

We first performed sensitivity analyses for universal testing, exploring methods to reduce costs and inefficiencies: saliva sampling instead of nasopharyngeal sampling (approximately 90% comparative sensitivity,[45–50] sampling time halved); saline rather than specific viral transport media (no loss in sensitivity[51]); heat extraction instead of reagent-based extraction (approximately 91% comparative sensitivity[52–54]); and pooling of 4 samples for RT-PCR (no loss in sensitivity[55,56]) (Appendix 1, Table e6). We also performed other sensitivity analyses for universal testing. We performed 1-way sensitivity analysis for costs, human resource inputs and estimated number of contacts for strategies 1 and 4. As these 2 strategies represent different organizational models for sampling (contacts are tested at clinic-based facilities, while workers will be tested at their worksites), the results are shown with tornado diagrams. We examined changes in costs and human resource needs if testing uptake (consent) was 90%, 80% or 60%. We estimated additional costs and human resource needs if

whole-blood sampling for serologic testing with an enzyme-linked immunosorbent assay was done concurrently with sampling for RT-PCR. To see how sensitive estimates were to prevalence of SARS-CoV-2 infection, we multiplied our estimated prevalence by 2 and by 10 and recalculated costs and human resource needs.

Ethics approval

Ethics approval was not required for this study.

Results

Analysis of universal testing

Costs, human resources and laboratory capacity for each strategy implemented across Canada are shown in Table 1 and Table 2, and for each province in Appendix 1 (Table e8).

The status quo testing approach from July 8 to 17, 2020 — 41 751 tests per day across 488 sampling centres — cost an estimated $2.4 million per day ($67.8 million per month), and required 755 nurses, 213 nursing assistants, 172 other health care professionals, 3261 clerical and nonclinical staff, and 721 laboratory staff (5122 personnel total). Changes in laboratory capacity and human resource needs with each strategy are shown in Figure 1.

Strategy 1: systematic tracing and testing of contacts

As shown in Table 1 and Table 2, systematic contact tracing and testing in addition to the status quo required 47 353 tests per day. All provinces had sufficient laboratory capacity (Appendix 1, Table e8). Clerical staff needs increased 1.2-fold to 3920 persons, and total monthly costs were $78.9 million (i.e., an additional $11.1 million per month over the status quo). The number of repeat tests required for positive individuals and negative contacts in this strategy was 180 840 per month, which would cost an extra $9.9 million.

Strategies 2 to 5: testing of at-risk populations

Table 1 and Table 2 detail human resource needs, laboratory capacity and costs of testing all members of at-risk populations on a single occasion. Testing of all hospital employees over a month required an additional 439 health care professionals, 890 clerical staff and 494 laboratory staff to sample 27 146 employees per day; the total cost was $29.0 million. For community health care workers and long-term care facilities, to test this population over a month, 4977 health care professionals and 5484 clerical staff would be needed to sample 35 620 people per day, with a total cost of $124.8 million. Testing all 2 568 496 essential employees with major interpersonal or public contact over a month would require 11 550 health care professionals and 12 837 clerical staff and cost $321.7 million. Finally, testing all 6 012 144 students and employees in primary and secondary schools over 1.5 months would require an added 20 956 health care professionals, 22 950 clerical staff and 2462 laboratory staff, costing $816.0 million. Costs, human resources and laboratory capacity required when conducting testing of at-risk populations with systematic contact tracing and testing are shown in Table 1 and Table 2.

Table 1: Daily human resource and laboratory capacity needs for active testing strategies for SARS-CoV-2 across Canada

			At-risk populations			
Outcome category	Status quo: current strategy*	Strategy 1: systematically trace and test contacts (in addition to status quo)	Strategy 2: test all employees of acute care hospitals	Strategy 3: test all CHW and employees and residents of long-term care facilities	Strategy 4: test all essential employees with major public or interpersonal contact	Strategy 5: test all children and staff of schools
Duration of human resource and capacity needed, d	Continuous	Continuous	28	28	28	42
No. of people sampled per day	41 751	47 353	27 146	35 620	91 732	143 146
Primary analysis						
Human resource requirements†						
No. of health care professionals‡	1140	1385	439	4977	11 550	20 956
No. of clerical staff§	3261	3920	890	5484	12 837	22 950
No. of laboratory staff	721	818	494	613	1578	2462
No. of total personnel if including Strategy 1	–	–	7946	17 197	32 088	52 491
Laboratory capacity requirements						
No. of laboratory tests run per day	41 751	47 353	27 146	35 620	91 732	143 146
No. of laboratory tests run per day including Strategy 1	–	–	74 499	82 972	139 085	190 499
Sensitivity analyses¶						
*Saliva sampling***						
Human resource requirements†						
Change in no. of health care professionals‡	–	–	−194	−921	−2150	−4090
Change in no. of clerical staff§	–	–	−65	−921	−2150	−4090
Pooling samples 4:1						
Human resource requirements†						
Change in no. of clerical staff	+13	+19	+3	+3	+3	+2
Change in no. of laboratory staff	−473	−525	−322	−423	−1100	−1718
Laboratory capacity requirements						
Change in no. of laboratory tests run per day	−29 880	−33 465	−19 972	−26 216	−67 878	−105 928
Change in no. of laboratory tests run per day including strategy 1	–	–	−53 437	−59 680	−101 342	−139 393
All analyses together††						
Human resource requirements†						
Change in no. of health care professionals‡	–	–	−194	−921	−2150	−4090
Change in no. of clerical staff	+13	+19	−62	−918	−2147	−4088
Change in no. of laboratory staff	−473	−525	−322	−423	−1100	−1718
Laboratory capacity requirements						
Change in no. of laboratory tests run per day	−29 880	−33 465	−19 972	−26 216	−67 878	−105 928
Change in no. of laboratory tests run per day including strategy 1	–	–	−53 437	−59 680	−101 342	−139 393

Note: CHW = community health care workers, SARS-CoV-2 = severe acute respiratory syndrome coronavirus 2.
*As of July 17, 2020.
†The numbers required are the total number of people (working a total of 8 h) in each work category needed per day to carry out all tasks contained in our 6-stage framework.
‡For current strategy and strategy 1, 61%–68% of these health care professionals are nurses, 13%–14% are auxiliary (assistant) nurses, and 1%–2% are physicians. For strategies 2–5, 91%–98% of these health care professionals are nurses, 1% are auxiliary (assistant) nurses and 1%–3% are physicians.
§This also includes a small proportion of data managers (1%–3%), with the high end of the range necessary when contact tracing is implemented.
¶Categories included only if a change in human resource or laboratory capacity requirements occurred.
**Saliva sampling employed only for large-scale, prevalence-based testing programs in at-risk populations (strategies 2–5).
††Combination of saliva and pooling samples.

Table 2: Costs for conducting active testing strategies for SARS-CoV-2 across Canada

Outcome category	Status quo: current strategy*	Strategy 1: systematically trace and test contacts (in addition to status quo)	At-risk populations			
			Strategy 2: test all employees of acute care hospitals	Strategy 3: test all CHW and employees and residents of long-term care facilities	Strategy 4: test all essential employees with public or interpersonal contact	Strategy 5: test all children and staff of schools
Time frame for cost calculation, d	28	28	28	28	28	42
No. of people sampled per day	41 751	47 353	27 146	35 620	91 732	143 146
No. of people to sample over time frame	1 169 028	1 325 872	760 095	997 350	2 568 496	6 012 144
Primary analysis						
Costs, $						
Per 100 persons tested	5800	5950	3820	12 520	12 520	13 570
Per day	2.4 million	2.8 million	1.0 million	4.5 million	11.5 million	19.4 million
Total over time frame	67.8 million	78.9 million	29.0 million	124.8 million	321.7 million	816.0 million
Total cost including strategy 1	–	–	107.9 million	203.7 million	400.6 million	934.3 million
Additional considerations						
No. of additional tests for contacts or repeat testing over time frame†	19 605	180 840	33 790	43 350	43 950	52 600
Total cost of additional tests, $	1.2 million	9.9 million	2.1 million	2.8 million	2.8 million	3.3 million
Sensitivity analyses‡						
Saliva sampling§						
Cost savings over time frame	–	–	–5.3 million	–39.6 million	–91.4 million	–257.6 million
Saline transport media						
Cost savings over time frame	–3.9 million	–4.4 million	–2.5 million	–3.3 million	–8.5 million	–20.0 million
Cost savings if implemented with strategy 1	–	–	–6.9 million	–7.7 million	–12.9 million	–26.6 million
Heat extraction						
Cost savings over time frame	–12.3 million	–14.0 million	–8.0 million	–10.5 million	–27.1 million	–63.5 million
Cost savings if implemented with strategy 1	–	–	–22.0 million	–24.5 million	–41.1 million	–84.5 million
Pooling samples 4:1						
Cost savings over time frame	–15.5 million	–17.3 million	–10.4 million	–13.6 million	–35.4 million	–83.1 million
Cost savings if implemented with strategy 1	–	–	–27.7 million	–31.0 million	–52.8 million	–109.1 million
All analyses together¶						
Cost savings over time frame	–22.9 million	–25.8 million	–17.7 million	–56.3 million	–135.2 million	–356.8 million
Cost savings if implemented with strategy 1	–	–	–43.6 million	–82.1 million	–161.1 million	–395.5 million

Note: CHW = community health care workers, SARS-CoV-2 = severe acute respiratory syndrome coronavirus 2.
*As of July 17, 2020.
†Assuming all people who test positive need 2 additional tests (all strategies), all negative contacts need 1 additional test (strategy 1), and all new contacts traced require a test (strategies 2–5).
‡Categories included only if a change in cost occurred.
§Saliva sampling employed only for large-scale, prevalence-based testing programs in at-risk populations (strategies 2–5).
¶Combination of saliva, saline transport media, heat extraction and pooling samples. Cost savings are not additive for 2 reasons: (1) pooling samples reduces reagent use and therefore reduces savings associated with heat extraction; (2) saliva sampling does not require viral transport media, so when saliva sampling is performed savings associated with saline transport media are embedded.
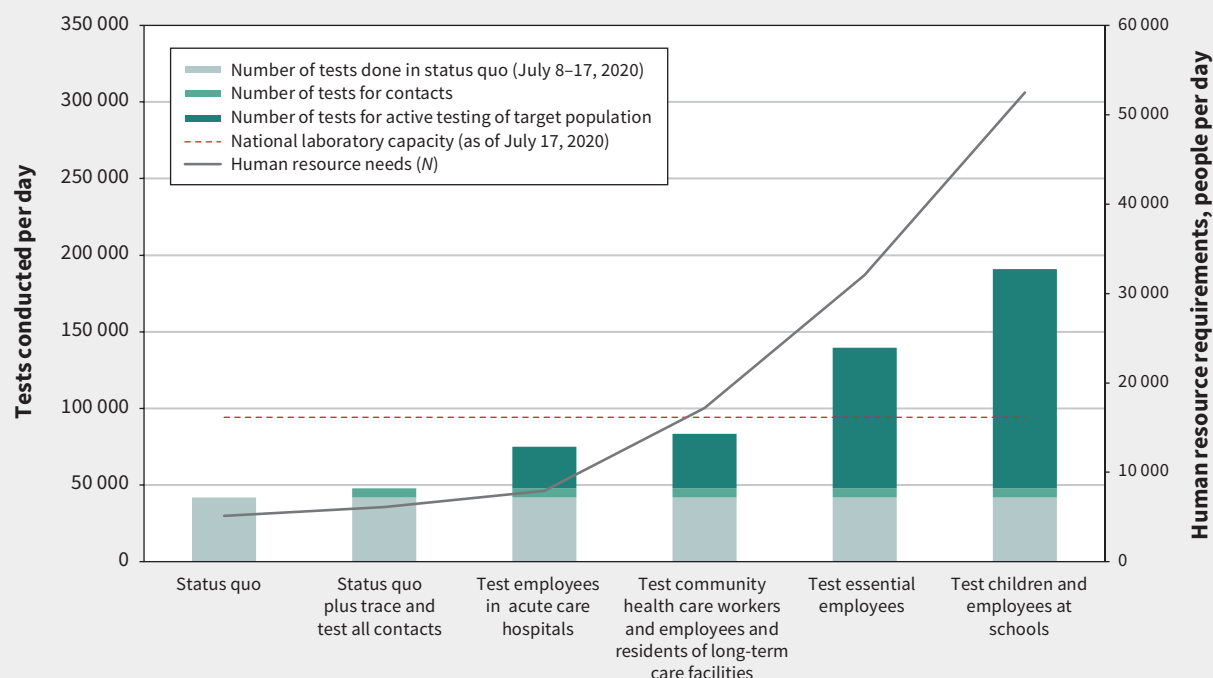
Figure 1: Changing laboratory capacity requirements across strategies, with attendant changes in total human resources (health care professionals, clerical staff and laboratory staff). Note: Total number of personnel required, and laboratory capacity needed for each strategy. The estimated national laboratory capacity (as of July 17, 2020) is denoted with the dashed line. For at-risk populations, incremental laboratory capacity needs are shown, assuming systematic tracing and testing of contacts is implemented and continued; total personnel are shown for these same at-risk populations assuming systematic tracing and testing of contacts is implemented and continued.

Analysis of surveillance and repeated testing

Cost and human resource estimates for surveillance testing in randomly selected samples of at-risk populations are shown in Table 3. Costs were estimated to be about 5% those of universal testing of at-risk groups. Estimated costs for each round of surveillance testing were $2.3 million for hospital employees, $6.6 million for community health care workers and employees and residents of long-term care facilities; $14.4 million for other essential workers; and $45.6 million within schools. Conducted individually, all provinces had laboratory capacity to conduct surveillance testing in 1 of these at-risk populations in parallel with systematic tracing and testing of contacts, but only 3 provinces had capacity to conduct surveillance testing simultaneously in all populations (Appendix 1, Table e9).

In our simulations, the critical determinant of the frequency of repeat surveillance or universal testing was the daily risk of acquiring SARS-CoV-2. If daily SARS-CoV-2 infection risk is 1 per 100 000 (corresponding to a population prevalence of about 0.01%), then population groups of 100 or fewer (e.g., smaller workforces or classes in primary or secondary schools) would be more than 90% likely to remain infection free for more than 3 months, and testing could be repeated quarterly. In contrast, if daily SARS-CoV-2 infection risk is 1 per 10 000 (population prevalence of about 0.1%), then groups of 100 or fewer would be more than 90% likely to remain infection free for about 4 weeks or more, suggesting testing should be repeated monthly. Larger groups, or higher infection risk, would require repeated testing at shorter intervals (Appendix 1, Table e10).

Sensitivity analyses

Implementing interventions to reduce costs and improve efficiency were predicted to substantially affect resources required for universal testing (Table 1, Table 2). Saliva-based sampling would reduce costs by 25%–30% and nursing and clerical resource needs by about 20%. Conversely, heat extraction and saline transport media did not reduce resource needs as substantially. Pooling samples 4:1 could reduce reagents and laboratory technician time by nearly 70%. All improvements combined reduced total costs by 40% and personnel needs by 20% for strategies involving at-risk populations. In 1-way sensitivity analysis, cost of systematically tracing and testing contacts was most sensitive to RT-PCR reagent cost, and personnel needs were most sensitive to activities related to tracing and scheduling contacts. For testing at-risk essential workers, both cost and personnel needs were most sensitive to the time required to obtain samples (Appendix 1, Figure e2). Reduced acceptance of testing resulted in parallel reductions in human resource requirements and costs (Appendix 1, Table e11). Performing serologic sampling and testing alongside RT-PCR cost an additional $31 per person, based on an assumed manufacturers' cost of $10 per test (Appendix 1, Table e11). Analyses considering increased prevalence of SARS-CoV-2 infection resulted in proportional increases to the number of contacts traced and tested in all strategies, but minimally affected cost and human resource needs for strategies in at-risk populations (Appendix 1, Table e12).

Table 3: Costs, testing capacity and human resource needs for conducting SARS-CoV-2 surveillance testing across Canada over 14-day intervals

Outcome category	Employees of acute care hospitals	CHW and employees and residents of long-term care facilities	Essential employees with public or interpersonal contact	Children and staff of schools	All groups at once
Situation on July 17, 2020					
Estimated SARS-CoV-2 prevalence in population, %	0.25	0.25	0.1	0.05	–
Total no. of people to sample*	60 942	30 462	86 951	302 313	408 668
Human resource requirements					
No. of health care professionals	73	588	1235	3633	5529
No. of clerical staff	145	619	1322	3933	6019
No. of laboratory staff	79	37	107	371	595
Laboratory capacity requirements					
No. of laboratory tests run per day	4353	2176	6211	21 594	34 333
Costs to test all, $	2.3 million	6.6 million	14.4 million	45.6 million	69.1 million
Situation if prevalence was 10 × higher					
Estimated SARS-CoV-2 prevalence in population, %	2.5	2.5	1.0	0.5	–
Total no. of people to sample†	48 728	19 391	56 403	198 776	323 298
Human resource requirements					
No. of health care professionals	58	379	801	2404	3642
No. of clerical staff	116	399	857	2601	3973
No. of laboratory staff	63	24	69	244	401
Laboratory capacity requirements					
No. of laboratory tests run per day	3481	1385	4029	14 198	23 093
Costs to test all, $	1.9 million	4.3 million	9.3 million	30.2 million	45.7 million

Note: CHW = community health care workers, SARS-CoV-2 = severe acute respiratory syndrome coronavirus 2.
*All sample sizes calculated based on having a relative precision of 100% for the 95% confidence interval around the estimated SARS-CoV-2 prevalence.
† All sample sizes calculated based on having a relative precision of 50% for the 95% confidence interval around the estimated SARS-CoV-2 prevalence.

Interpretation

Our analysis shows that actively testing populations at increased risk of acquiring SARS-CoV-2 in Canada can be feasible. Systematic tracing and testing of 16 contacts per person given a new diagnosis of SARS-CoV-2 infection marginally increases testing costs and could be accomplished with current laboratory capacity. The cost of universal testing for at-risk populations would be $1.3 billion for 1 round of testing. Even if repeated, these costs represent a small fraction of the $169.2 billion in Canadian federal fiscal response to the COVID-19 pandemic (as of June 2020). Implementing interventions to reduce inefficiencies in sampling and laboratory procedures could substantially reduce these costs. Surveillance testing — for which capacity already exists — is an important and less costly approach to understanding the extent and dynamics of SARS-CoV-2 in at-risk populations.

Our findings place into context the substantial response needed to ensure regular testing can be provided to populations who need it most. These resource and population size estimates are useful for other jurisdictions seeking to implement active testing strategies for SARS-CoV-2. In Canada, the populations targeted for active testing are large — some 4 million people in hospitals, community health care, long-term care and essential businesses, and 6 million within schools — but others have advocated for a similarly ambitious approach.[57–59] In other countries, such as South Korea,[60] Hong Kong[61] and Germany,[62] testing capacity was rapidly expanded to help control the initial epidemic wave. Innovative programs to expand testing, like the Rapid Acceleration of Diagnostics (RADx) program in the United States,[63] are also under way. These examples show massive testing programs are possible when governments prioritize efforts, provide adequate funding, involve all sectors and leverage human resources.

The most important benefit of an active testing approach is the identification of people infected with SARS-CoV-2 who have minimal or no symptoms and are currently undetected. The approach to preventing transmission from such individuals during the first wave of COVID-19 in Canada was to shut down many activities. This has had major social and economic consequences. We suggest that actively testing those at increased risk

of acquiring SARS-CoV-2 — and isolating individuals found to be infected — could be equally effective to arrest community transmission and is associated with far less social and economic cost.

There are other potential benefits to our proposed approach. These include strengthening of public health and laboratory capacity, which is essential to prevent recrudescence. Such public health capacity could also be leveraged for eventual coordination and implementation of vaccination against SARS-CoV-2. Active testing will also provide critical epidemiologic data necessary for decisions on further testing or control measures. By initiating surveillance testing immediately, evidence-based decisions on further testing entire groups could be made as capacity is built. If groups are found to have a low prevalence of SARS-CoV-2 infection, routine surveillance testing would be essential to rapidly respond to increases. Additionally, unused capacity could be diverted to testing entire groups with higher prevalence more frequently and rapidly. Gathering samples for both serologic[64,65] and RT-PCR testing to detect previous and current infection could add considerably to the epidemiologic value of active testing, particularly as the epidemic continues.

Rapidly scaling human resource and laboratory capacity is critical to the success of these strategies. This may be supported by engaging medical students,[66] leveraging other health care professionals[67] and using academic and private laboratories.[68] Our sensitivity analyses also highlight other approaches that may expedite scale-up. The most notable is gathering saliva samples. This form of sampling would be more acceptable — particularly to children, a key consideration when schools reopen — and has excellent sensitivity.[45–50] Saliva samples also eliminate the need for nasopharyngeal swabs, a trained health care professional to perform sampling, and the use of costly and scarce PPE.

Limitations

Much of how SARS-CoV-2 sampling and contact tracing is performed was derived from Quebec during the first wave of the pandemic, although this was validated with other settings.[69–73] There is heterogeneity among provincial health systems, and the epidemiology of SARS-CoV-2 is changing rapidly. We conducted sensitivity analyses applicable to other scenarios, such as epidemic resurgence, and new approaches — such as the approval of accurate, inexpensive point-of-care tests — can be implemented with the tool we developed.[74] We did not, however, estimate potential epidemiologic impacts of active testing, although we expect increased testing and contact tracing would help reduce community transmission, resulting in substantial downstream health system savings. For contacts, other studies have estimated impacts.[75–77] It is possible some people in our strategies are already being tested (e.g., some contacts) and other groups that may require testing (e.g., travellers, visitors to long-term care) were not considered. We used a strict definition for essential workers. As workplaces such as bars and fitness centres reopen, and industries such as air travel see increasing customer volumes, more workers will be at increased risk of acquiring SARS-CoV-2. We did not consider costs associated with capacity building and existing infrastructure; nor did we include health system costs beyond testing, such as inpatient or outpatient medical costs, as most people detected would be unlikely to seek care or be detected otherwise.

Conclusion

As workplaces and schools reopen after the first wave of COVID-19 in Canada, testing priorities and strategies are needed to prevent surges in community transmission of SARS-CoV-2. Active testing strategies can identify a high proportion of people with SARS-CoV-2 infection and minimal or no symptoms, who are currently an important source of community transmission. We believe that a strategy of actively testing large population groups who are at increased risk of acquiring SARS-CoV-2 is feasible and affordable in Canada. This testing approach should be an integral component of a broad strategy to allow all Canadians to return safely to work and school.

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